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From BULLETIN OF THE BUREAU OF FISHERIES, Volume XXVIII, 1908

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PROPAGATION AND PROTECTION OF THE RHINE SALMON

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By P. P. C. Hoek, Ph. D.

Scientific Fishery Adviser to the Dutch Government

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Paper presented before the Fourth International Fishery Congress
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PROPAGATION AND PROTECTION OF THE RHINE SALMON.

By P. P. C. HOEK, Ph. D.,
Scientific Fishery Adviser to the Dutch Government.

ENVIRONMENTAL CONDITIONS AND NATURAL HISTORY.

Wherever it is found the salmon is highly esteemed—to the most precious kinds of salmon that of the Rhine unquestionably belongs.

"Old Father Rhine," with his very important tributaries, flows through a very densely populated part of west Europe—at the same time one of the most industrious and cultivated regions of the whole world. The river itself, as you all know, comes from Switzerland, forms the frontier between that country and the Grand Duchy of Baden, passes through a great part of western Germany, then enters Holland, and in that country, with numerous outflows, finds its way to the North Sea. Of the numerous affluents, which together drain a surface of several thousands of square miles, some belong to Switzerland, many belong to Germany, a few to the Low Countries (the Netherlands) nearer the mouth of the river.

It is impossible to treat of the propagation of the salmon of the Rhine without emphasizing the important rôle the affluents play in the economy of this fish. As a rule the Rhine salmon does not propagate on the main river itself, but for that purpose enters one of the tributaries, there to spawn in the upper courses or in the mountainous rivulets and brooks which are in open communication with these upper waters. The main river itself plays only a secondary part, so to say, in the natural history of our fish; it forms the communication, the open highway, between the sea and the very extensive region where the natural propagation takes place. It is now a well-established fact that the greater part of the young salmon hatched in the higher parts of the affluents of the Rhine remain there about a year, living in that time the life of trout, and as 1-year-old fish, in springtime, migrate to the sea. They reach the mouth of the river on their way to the ocean in the month of May, their length being then from 12 to 17 centimeters. Most of these young salmon at that time have already, or at least partly, changed their trout livery (the "parr" costume), with

the well-known transverse black bands, the small red spots, etc., for a more convenient traveling suit of silvery gray, and in this condition they are called "smolts."

The main river, which has served for the passage of the yearlings on their way to the ocean, a few years later conducts the grown-up fish to their spawning places; so the river itself is mainly the binding link between the sea, where the salmon grow up from 15-centimeter large trout-like fish to marketable salmon, and the upper region, where the propagation takes place and the young salmon find a living until they are about 1 year old. The food the young salmon take in the main river during their journey to the sea consists of different insects, and in the lower parts of the river and the estuaries small crustaceans. During the ascent of the larger fish coming from the sea and bound for the spawning places in the river, as a rule no food whatever is taken. The salmon caught during their ascent owe their value as food for man to the rich feeding grounds in the open sea. So it is perfectly right to consider them as a gift from the sea to the lands bordering on the river, the inhabitants of which catch them on their passage. But taking into consideration the fact that the salmon swim up the river at the expense of the fat stored in their muscles, etc., from a general economic point of view it is also evident that the fish are in finest condition on entering the river, and that therefore the lower parts of the river are most to be recommended for the catching of the salmon.

Now, keeping constantly in our mind the importance of the upper regions of the river and its tributaries for the first year of the salmon's life and that of the open sea for their growth until they shall have reached marketable size, I shall first of all point out to you that this normal course of development is not followed by those young salmon which at the end of their first year remain for a second year, and some of them longer still, at or in the neighborhood of their birthplaces. These are nearly all male fishes, and it is a well-established fact that they will be sexually mature (ripe) in the second autumn of their existence, and then even will play an active part in the propagation of the species. Their size is (October–November) from 15 to 19 centimeters, very few being smaller or larger than that size. It has been suggested by Professor Fritsch for the salmon of the river Elbe that all the young males may remain a second year in the upper parts of the river and its affluents. I have been able myself to show, however, that this by no means holds good for the Rhine. I had the opportunity of examining 365 young salmon caught in May during their descent to the sea in one of the mouths of the Rhine, and measuring from 12 to 17 centimeters, and I found that 136 (37 per cent) of these were males and 229 (63 per cent) females. Males and females were exactly of the same sizes, and it can hardly be doubted that they were all of them 1-year-old fishes. That there was a majority of females may, of course, be considered in connection with the circumstance

that the salmon that remain in the river for a second year or longer are to a very large extent males.

Regarding these latter males, another suggestion has been made by myself, viz, that they will never descend to the sea, but will die after once, others twice, perhaps, having taken part in the propagation of the species. This suggestion is based on the fact that no descent of larger young salmon hitherto has been observed, though the means of making such observations have not been wanting. I have not been able, however, to prove in a direct way the exactness of my hypothesis.

Another point to which I may be permitted to call your attention is that when I said that "grown-up" fish return from the sea and enter the river, if possible to reach the spawning places, the age and in consequence the size of these fishes, and their state of maturity as well, are extremely different. It is of course easy enough to determine the size of the salmon entering the river. Miescher-Ruesch, who did the same (in 1878 and 1879) for salmon caught near Basel and who for the first time applied the graphical method afterwards introduced into science for other fishes as the "Petersen method," found that the curve of the sizes of the salmon of the Basel market is one with three tops or maxima, making it clear at once that three different ages were represented, and showing with great evidence at the same time that the difference in age between the youngest and middle-aged salmon was about the same as that between the latter and the oldest fish caught.

To check the results arrived at by the Basel professor, I ordered to be measured for me (1893) a large number of salmon caught near the mouth of the Rhine and offered for sale at the Kralingsche Veer market. From March to December 4,653 salmon were measured, and the curve constructed with these figures corresponds in the main with that given by Miescher-Ruesch for the Basel salmon. The salmon of the Rhine (fig. 1) present themselves in three sizes: Smallest, 54 to 74 centimeters, mean 64 centimeters (2 to 4 kilograms); middle size, 74 to 98 centimeters, mean 88 centimeters (6 to 10 kilograms); largest, 98 to 134 centimeters, mean 106 centimeters (12 to 25 kilograms).

The fishes of different sizes do not enter the river together or in a haphazard way. The different sizes present themselves in different seasons, but they do in one year exactly as in any other (fig. 2).

The smallest fish (grilse) are called St. Jacob salmon in Holland. They ascend the Rhine in July and August, exceptionally few coming in June; they continue to ascend in September, though in smaller numbers than in the foregoing months, and even in October and November a few may still be taken. They are most of them males and they are all of them in so far advanced a state of maturity that they will be able to take an active part in the propagation of the species a few months or weeks or days after their arrival. This holds good

also for the female grilse, though the males are by far in the majority. Of the grilse, as far as our observations go, not more than 17 per cent are females.

The middle-sized salmon (of 74-98 centimeters) are the so-called "small summer salmon" of the Dutch market. They present themselves for the first time in the river in May, and they continue to ascend until the end of the year. They are most numerous in June and July, but they form also a very important

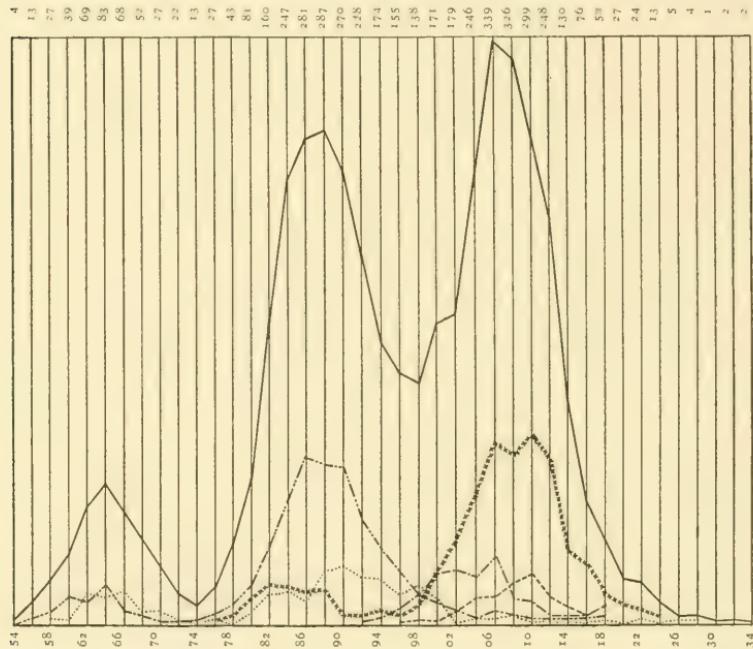


FIG. 1.—Diagram illustrating the sizes of salmon ascending the Rhine. The lengths, in centimeters, are given at the lower ends of the vertical lines. The number of specimens of each length is given at the upper end of the proper line. The total number of specimens measured was 4,653.

—	Salmon of March-December.	— · — · —	Salmon of July.
- - -	Salmon of March.	· · · ·	Salmon of September.
XXXXXX	Salmon of May.	- - - -	Salmon of November.

part of the August and September salmon. Both males and females appear among these salmon, but the females are in the majority. Though the first arrivals are far from being mature, all these small summer salmon are destined to take part in the propagation of the species toward the end of the autumn.

The large salmon (the fish of 98-134 centimeters) begin to ascend in November, though in some years a few may be taken in October. They are at that time

so far from being mature that until lately they have been considered as quite sterile animals. It has been shown, however, by the investigations of Miescher-Ruesch and myself, that these salmon are by no means sterile, but only immature fish and that they will develop their sexual organs in the course of the year and during their residence in the fresh water. Some are males and some females, the latter, however, being in the majority. They are not very numerous in the winter months, but gradually their number increases; they are very fat and of the highest value as human food. They continue to ascend in spring, are most numerous from March to May, and go on ascending until the spawning time. From the beginning of their ascent until far up in spring they are called "winter salmon;" they are the same salmon, however, as those which from April or May until the spawning time in November and December are called "large summer salmon." Their sexual organs, which are in quite an undeveloped condition in November and December, are slightly more developed in the fish of February, March, and so on. In May their state of maturity is exactly the same as that of the so-called "small summer salmon," which then begin to ascend; for both categories of fishes—and the same holds good for the third category, the St. Jacob salmon, which ascend from July—the date of their entering the river is, generally speaking, a measure of the state of development of their sexual glands. The further development of these organs will take place during their stay in the river itself, and as these fish take no food during their sojourn in the fresh water, it is at the expense of the nutritive matter stored in their muscles, in the lateral muscles of the trunk especially, that the maturation takes place. From this it is clear at the same time that, the "winter salmon" of October and December being by far the most valuable fish of all, through the year the condition of the salmon deteriorates slowly but gradually until they reach maturity, with perfectly developed sexual glands (the weight of which may be over 25 per cent of that of the whole fish), but otherwise in extremely poor condition.

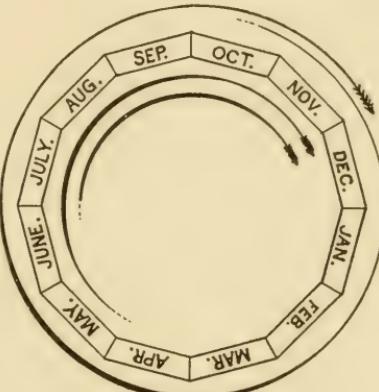


FIG. 2.—Diagram showing the ascent of the Rhine salmon in different months. The outer line, circumscribing the remainder of the figure, represents the salmon of the greatest size, which are called from October to April winter salmon and from May to December large summer salmon. The middle line represents the middle-sized salmon, which are called small summer salmon. The inner line represents the smallest salmon, which are called St. Jacob salmon (grilse). The dotted part of each line indicates when the salmon begin to ascend, the swollen part when their numbers are greatest, the feathered end part when they are ripe for spawning.

I do not wish to enter into detail upon the physiological part of this subject, however; it has been studied with great care by Professor Miescher-Ruesch, of Basel, who on the same occasion published an excellent description of the histological changes of the milt of the salmon, which changes occur during that development of the sexual organs. Later investigations (of Noël Paton and others) have in the main confirmed the results arrived at by the Swiss physiologist.

These are the headlines of the natural history of the Rhine salmon; the same fish as occurring in other European rivers has perhaps not been studied quite so carefully as the Rhine salmon, but from what we know about the other rivers, which after all is not so little, we may safely conclude that the salmon behave about the same all over Europe.

PROPAGATION.

About the propagation of the Rhine salmon few words need be added. We saw that the natural propagation takes place in the upper parts of the tributaries, the spawning places being well known to the inhabitants and being easily distinguished from the shore, especially when the water is clear and the depth unimportant. Some of the fish, however, spawn in the main river itself, spawning beds (Laichgruben) having been observed in the Rhine between Strasburg and Basel, as also between Basel and Schaffhausen. Whether spawning in the main river takes place regularly or only accidentally has never been investigated thoroughly; in fact, even for a fish so much studied as the Rhine salmon, in some regards information is wanting which after all might perhaps not be so difficult to obtain.

The real spawning places of the Rhine salmon, it is easily understood from the foregoing, spread over a wide area situated for the greater part in Germany and for a smaller one in Switzerland. The relative richness in salmon which the Rhine even at present possesses is unquestionably to a very large extent due to the wide reaches of its tributaries, the spawning places of our fish. That richness would undoubtedly be much greater if more salmon were permitted to reach these spawning places, if these places were better protected, that the salmon might propagate undisturbed, and if all the young salmon hatched in the upper regions of the river could safely arrive in the ocean.

There can be no question that on the Rhine relatively few salmon nowadays come to spawning in the natural way. Of some of the tributaries (of the Moselle especially, but of some of the affluents in the Grand Duchy of Baden also) I studied the upper regions in this regard, and the result has not been very edifying. The fish reaching the upper region, the number of which is limited by the fishing in the lower and middle regions of the river, are sought with great eagerness. Though their value as food, especially in the very last days and weeks before the spawning, is, comparatively speaking, a small one, they

represent for the fishermen of the upper regions, most of whom belong to the poorer classes of society, a precious contribution to their earnings. The higher the fish ascend, the narrower the tributaries and brooks, the easier to catch the big fish, which in their particular condition are, moreover, slow and lazy in their movements. In consequence very few fish escape; in other words, the number of those spawning in the natural way is as a rule extremely small. I do not hesitate to say that if the keeping up of the stock of salmon depended on natural propagation only the salmon production of the Rhine by this time would be very poor.

Artificial propagation has tried, and I think not without success, to remedy this deficiency. A good many of the salmon caught in ripe condition, or nearly so, in the upper regions of the river are used for artificial hatching and from these several millions of fry have been produced annually for many years. They have been set free in the most suitable waters, that is to say, mostly in those smaller brooks and tributaries where the salmon would have spawned in the natural way if man had not interfered with their intentions. An arrangement was made, first by Baden, Switzerland, and the so-called Reichsland (Elsass-Lotharingen) and a few years later (1890) by Holland, the different German states bordering on the Rhine, and Switzerland, annually to set free a certain number of salmon fry, and quantities varying from 4 and 6 to 7 millions of young salmon accordingly were bred each year. They are planted almost immediately after the resorption of the yolk vesicle, sometimes also a little before the young salmon have developed so far. They are distributed over a large area of the upper course of the river, and, as I pointed out before, if possible at such places only as salmon are accustomed to seek to spawn in the natural way. Against this procedure an objection was raised that the distance between these spawning places and the open sea is a long one, and that numerous dangers threaten the young fish during their stay in the upper parts of the river and during their descent to the sea as well. It looks at first sight as if these dangers might be avoided by cultivating the fry near the mouth of the river and by keeping them longer in tanks or ponds at the hatchery; but as only very few ripe fish are taken in the lower parts of the river, the culturist is obliged to collect unripe salmon several weeks before the spawning and to keep them in reservoirs floating in the river until they are ripe; or, if he does not like that way of doing, to order eggs from the upper parts, which eggs, once the eyes of the embryo have become visible, endure the transportation well.

Comparing this way of proceeding with the culture at or near the spawning places, and keeping in mind that it is a well established fact that in free nature the young salmon in the upper regions of the river live at least one year the life of young trout, since studying the salmon and the salmon development I have always been convinced, and am still at the present time, that the most

efficacious way of propagating the salmon artificially is to stick as closely as possible to the natural way and to plant the fry in those mountainous courses of the river where their natural home is found. This is not to shut our eyes to the dangers threatening the young salmon during their passage to the sea—in my opinion the best way to avoid this danger is not, however, to grow them in a more or less artificial way near the mouth of the river, but to stock the natural spawning places so richly that a sufficient portion remains, even if a large number of them is destroyed during their stay in the upper parts and their descent to the sea. The solid ground of nature is in this, as in so many other cases, the best to build upon.

FISHING REGULATIONS.

Now coming to the second part of my little discourse, I prefer to give you the headlines only of the existing regulations of the Rhine salmon fishing. You know that the Rhine flows through different countries, and you understand that regulation of the fishery in such an international river based on international agreement for a long time has been considered as the best—as the only efficacious one. The first serious effort to conclude an international treaty between the countries interested in the salmon fishing of the Rhine dates from 1869, but the war of 1870 postponed for several years the conclusion of such a treaty. New negotiations were taken up about 1884, the treaty was concluded in Berlin in 1885, and has now been in force since August, 1886. Originally it was concluded for ten years, after that period each of the powers interested having the right to break off the engagement with one year's warning. Though the treaty has perhaps not quite satisfied those who expected from it great betterment of the salmon fisheries of the Rhine, there has never been seriously a question of giving it up.

As far as the Netherlands are concerned, as a good regulation of the salmon fishery existed already, important changes were caused by the treaty in two regards only—the closing of the fishery on Sunday and the closing of the fishing with big seines a fortnight earlier (on the 15th of August) than hitherto. These changes are quite in accordance with the general idea of the treaty. Those who fish in the lower parts of the river are to spare a considerable part of the ascending salmon, that those fishing higher up may profit by this and also that part of these fish may reach the upper region, there to spawn. The fishermen of the middle and higher regions, on their part, must also take into consideration the interests of the whole river. They are to spare a part of the ascending fish for natural propagation. They are to take into their custody the natural spawning places and moreover to take care that ripe or nearly ripe fish caught in spawning time are used for artificial reproduction.

Methinks the treaty, which is based on sound principles, has, taken as a whole, worked well. If nevertheless on several occasions complaints have been heard on its efficacy, we must not forget that those who find fault with it most were from the beginning too optimistic in their expectations. After all, human nature is not changed by an international treaty, and the nature of fishermen is as human as that of other people. Those who are interested in the fisheries of the middle and upper river claimed, when the treaty was being closed, a greater part of the ascending fish, and through the treaty's influence they have no doubt received that. What is more natural than that they might go further still in the same direction and should like to receive a greater share still in the future? Those who fish in the lower parts of the river, and by the treaty are compelled to spare more of the ascending fish than they were accustomed to do before, complain that the richness of the river in salmon has not augmented since the treaty was closed. They say, "We did not close the treaty only for giving a good deal of the fish we can catch ourselves to our neighbors of the middle and upper regions, but we did so that the spawning region might be better stocked with breeders. If all the fish, or too many of them, we spare are caught higher up the river, what good can come of our savings?" No wonder that they ask for measures better to protect the spawning fish.

I think, however, that it would be hardly interesting and by no means amusing for you to hear me discuss this question any longer or to go over the different articles of the treaty with you. To understand their meaning, a good deal of technical information regarding the natural condition of the river and its different parts would be necessary, and I should spare you such details. I think it will be more interesting for you to hear something about the actual condition of the salmon fishing of the Rhine.

IMPORTANCE OF THE FISHERY.

I need hardly point out to you, who know about the fisheries of your own country, that it is very hard work for a big and precious fish like the salmon to maintain itself in a river like the Rhine, flowing through one of the most populated and flourishing parts of Europe, where all the circumstances seem to cooperate to destroy it and to prohibit its propagation. It is not only the direct influence of man, whose highly developed fishing industry is disastrous after all, that our fish has to reckon with. Indirectly, regardless of the fisheries, man, by normalization and regulation of the river and its affluents, did what he could to spoil and at several places to close the river for the ascent of the future spawning fish. Man moreover polluted the river with the sewage of his towns and with the poisonous waters of his manufactories, his mines, etc. And man, finally, by developing the river navigation, by using the water for

industrial purposes, all in all did his utmost to modify the stream in a direction contrary to the interests of the ascending salmon and their propagation.

Up to the present, nevertheless, the Rhine distinguishes itself from the other rivers of North Europe (and from those of the Atlantic coast of North America as well) by the relative productivity of its salmon fishery—though I must point out at once that also for the Rhine the figures of the catches have greatly diminished from what they were, say twenty-five years ago. There exist no good statistics of the product of the salmon fisheries of the whole river; favored by special circumstances, however, those interested in the fisheries of the lower parts of the Rhine in Holland, embracing all the larger seine fisheries, have for many years been able to register carefully the figures of all the salmon caught in these waters. These are the fish landed and sold by auction at the market of Kralingsche Veer, near Rotterdam. We have these figures since 1871, and just to show you the importance of this auction, I give you the following summary:

Period.	Total number.	Annual average.
1871-1907 (37 years)-----	1,822,000	49,200
1871-1889 (19 years)-----	1,133,000	59,600
1890-1907 (18 years)-----	689,000	38,300
1899-1907 (9 years)-----	230,500	25,600

These figures show a very considerable diminution. We are not to forget, however, that partly in consequence of changes in the natural condition of the river, partly through the influence of the treaty, and partly through the high development of navigation in the lower parts of the river—Rotterdam harbor—the fishing of the so-called large seine fisheries, which means those selling their catches at the said market of Kralingsche Veer, is now by no means as good as it was twenty to twenty-five years ago. In consequence, the percentage of the ascending fish caught in the lower parts of the river and sold at the said market, before that period, was naturally much larger than it is at present. In other words, there is no reason to consider the decline of the Rhine salmon fishery as quite so important as might be concluded from studying the figures of the Kralingsche Veer market alone.

As, however, reliable statistics for the salmon fishing of the whole river are not available, it is impossible to calculate what part of the whole catch is represented by the fish landed at Kralingsche Veer market. It may be 50 per cent at present, it may be a little more, it may be much less. Last year at Kralingsche Veer market 31,000 salmon were offered for sale, and 9,500 more were landed at five other salmon markets in Holland. Still higher up the river in

Holland perhaps a few thousand more salmon were taken. Then comes the German part of the river, and finally that part where the river forms the boundary between Germany (Baden) and Switzerland and where important salmon fisheries are found; but as to the fish taken in the German and Swiss parts of the Rhine no reliable figures are published. Altogether an estimate of 65,000 salmon as taken in the Rhine during the year 1907 remains probably under the actual production. That year was by no means an exceptionally good one—it was slightly better only than the eight preceding years. A catch of 65,000 salmon in such a year gives us the right to say, I think, that, be its productivity no more so great as it was before, "Old Father Rhine" still is entitled to be called an important salmon river.

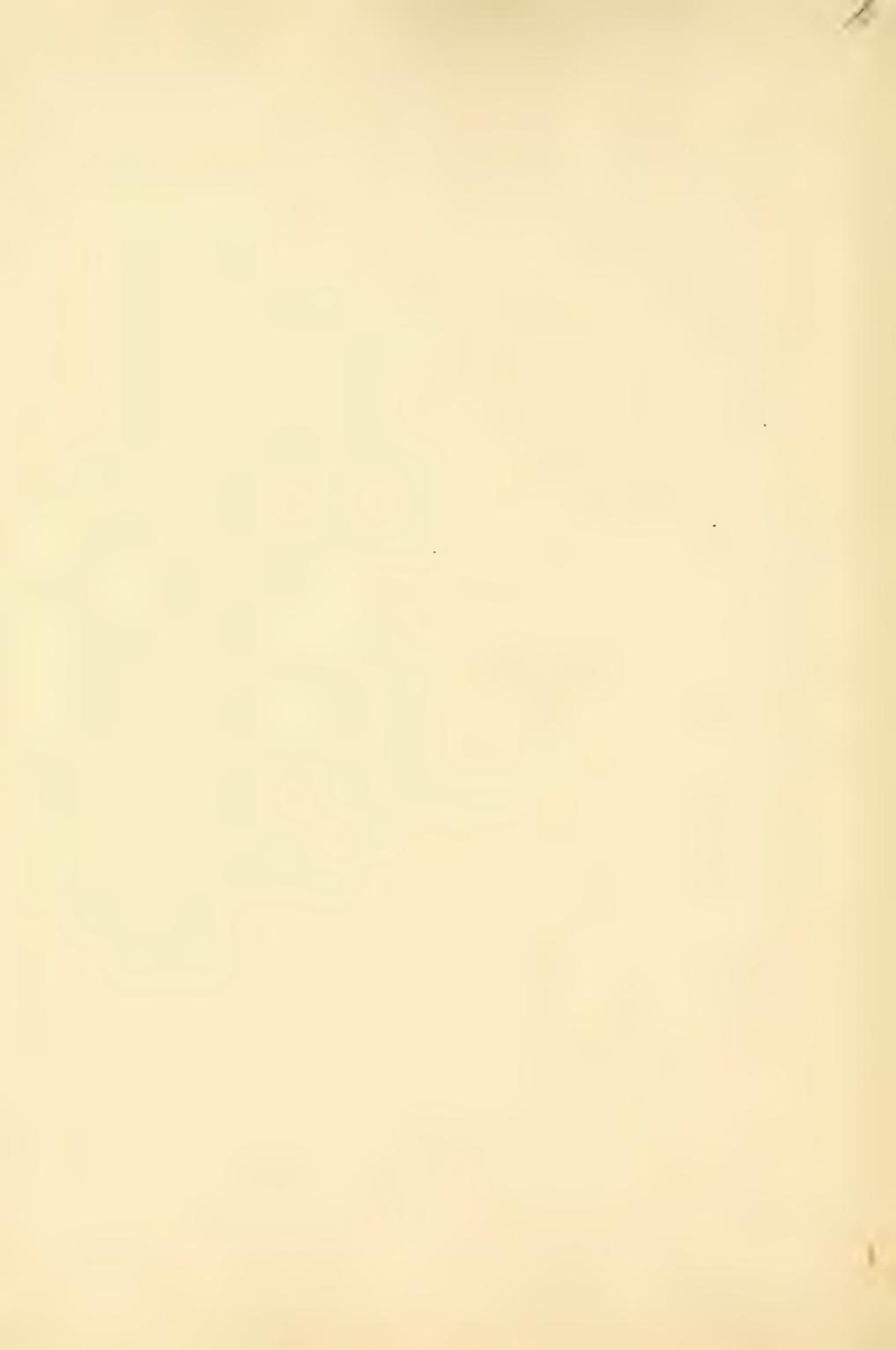
Now, it is my conviction, and I wish to conclude my little lecture by saying, that the Rhine to a very large extent owes to salmon culture the conservation of this production. The fact that the same river had more salmon before artificial propagation was begun does not disturb that conviction; that was at a time when natural propagation was still flourishing. Since the latter in the Rhine nearly quite belongs to history, only one way to keep up the stock remains, and that is by artificial propagation practiced in the most normal, most natural way.

DISCUSSION.

Prof. E. E. PRINCE. There is just one question I would like to ask Doctor Hoek, and that is as to the spawned salmon or kelts. How and when are those observed migrating, and what is the view in regard to their suggested destructiveness in salmon rivers, owing to their predacity?

Doctor HOEK. Mr. President, I thank you very much for the opportunity of telling you.

Kelts return to the sea every year, but not in very large numbers. It is true that our fishing is so organized that we catch the fish coming from the sea and not so well the fish coming down; yet at least some of these fish do not come down so very fast, but remain in a certain part of the river for some time, moving perhaps with the tide. We take some kelts every year. Doubtless it will be interesting to you, in the first place, to hear that most of these kelts are taken on the Rhine in Holland in the months of March and April, and not many earlier; in the second place that the sexes are represented in the kelts about as in the ascending fish, but that the males descend earlier than the females; and, in the third place (which I think is most interesting), that very large kelts have never been taken—the largest kelts we know are of the type of the smaller, so-called summer salmon (length 75 to 93 cm.), and do not belong to the big summer salmon or winter salmon. It remains only to tell you that we made some observations on the food found in the stomachs of the kelts, and that it was found to be indeed a very poor food. From what I have seen on the Rhine I must conclude that they are not accustomed to taking food on that river.



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